Khmer Rouge Irrigation Schemes During the Cambodian Genocide

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Between 1975 and 1979 Cambodia was witness to a period of mass violence in which approximately two million people died from famine, disease, and murder. This violence was the result of policies initiated by the Communist Party of Kampuchea, better known as the Khmer Rouge. To date, little research has systematically or empirically studied the geography of specific practices, notably the construction of irrigation schemes, initiated by the CPK that produced those material conditions that resulted in death and deprivation. Using satellite images, aerial photographs, archival records, and field observation, we systematically document and map Khmer Rouge irrigation schemes. Findings indicate that approximately 7,000 kilometers of canals and dikes and over 350 reservoirs were constructed during the genocide. A six-class typology is forwarded, as we argue that local hydrologic and geomorphic conditions did figure in the construction of dams, dikes, canals, and reservoirs.

Key words: Khmer Rouge, Cambodia, irrigation, structural violence, Democratic Kampuchea

Introduction

The Communist Party of Kampuchea (CPK; also known as the Khmer Rouge) is considered one of the most brutal and oppressive regimes of the twentieth century. Between 17 April 1975 and 7 January 1979 the CPK carried out a program of mass violence in Democratic Kampuchea (as Cambodia was renamed) that resulted in the death of approximately two million people.[1] Upwards of one million men, women, and children died from direct violence: torture, murder, and execution. The remainder died from starvation-related causes, lack of medical care, and exhaustion.

To date, much scholarly attention has focused on the direct violence that occurred throughout Democratic Kampuchea.[2] Less research has considered the structures of violence related to starvation, illness, or exhaustion.[3] Moreover, inadequate attention has focused on the *geography* of specific practices initiated by the CPK that produced those material conditions that resulted in widespread death and deprivation. Minimal work has empirically documented those practices associated with forced labor, rice production, or water-management. For example, scholars have mapped the location and distribution of security-centers and mass graves,[4] but there has not been any systematic attempt to document the location of agricultural collectives, grain warehouses, or irrigation schemes. In this paper, we partially redress these lacunae through an empirical mapping and documentation of Khmer Rouge irrigation schemes.

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It is frequently argued that policies of the CPK, but especially those concerning irrigation, were poorly designed and hastily implemented; that dams, dikes, canals, and reservoirs were prone to failure and led to widespread devastation.[5] Kevin McIntyre states simply that the Khmer Rouge "eschewed administrative apparatuses and bureaucracy."[6] Jeffrey Himel argues "irrigation works were built anywhere it was possible without consideration of the overall water requirements or stream capacity."[7] He continues "*most* of the irrigation works were deliberately built by a trial and error methodology" and that "the ambitious Khmer Rouge irrigation developed *failed catastrophically*, leaving the wreckage strewn across the landscape."[8] Daniel Bultmann likewise maintains, "the aim [of the CPK] was to build an environment defeating nature and operating purely in line with socialist functions, inhabited by pure socialist people, using pure revolutionary methods. This ideal socialist space aimed to operate *beyond natural conditions, geographic specifics and environmental diversity*."[9] We do not a priori dispute the conclusions of Himel and Bultmann; we do however see a need for a more sustained, empirically driven evaluation of Khmer Rouge irrigation practices. Indeed, James Tyner and Rachel Will provide documentary evidence that suggests the CPK did evince a more deliberate, comprehensive, and calculated approach to water-management.[10]

There does not exist a systematic inventory of the hundreds of irrigation projects initiated and/or completed by the Khmer Rouge; nor have these projects been quantitatively cataloged or mapped. Accordingly, in this paper we provide a systematic mapping and account of Khmer Rouge irrigation schemes. Between 2015 and 2017 we conducted a mixed methods survey of those dams, dikes, canals, and reservoirs constructed during the Khmer Rouge regime. Specifically, using satellite data and aerial images, archival records, and field observations we mapped Khmer Rouge irrigation schemes and develop a 6-class typology of these schemes. In short, through our reconstruction of Khmer Rouge water-management practices, we document that over 7,000 kilometers of canals were constructed and over 350 reservoirs were built. We conclude that the overall water-management of the CPK was decidedly more nuanced than heretofore acknowledged; that significant geographic and functional variation exists among irrigation schemes, indicating that local geomorphic and hydrological conditions were considered, but a comprehensive plan was lacking, thus contributing to localized failures.

Agriculture Under the Khmer Rouge

The physical geography of Cambodia consists of a large central plain, dominated by the Mekong River and the Tonlé Sap Lake, surrounded by a series of mountain ranges. Several small streams as well as the Tonlé Sap River, a tributary of the Mekong, feed the lake. Cambodia has a tropical climate dominated by two monsoons, a summer monsoon which starts in late May and brings heavy rains, and a winter monsoon which begins in November and brings dry, cool air. Heavy precipitation and thunderstorms throughout Southeast Asia during the summer monsoon cause the Mekong River to swell in size. This in turn causes the Tonlé Sap River to reverse its course and flow into the central basin, expanding the already vast Tonlé Sap Lake to five times its areal extent. Over the millennia, these climatic and geomorphic conditions have influenced farming practices, mostly lowland wet-rice cultivation, in a landscape dominated by villages and hamlets.

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A decidedly different geography was imagined and put into practice by the CPK.[11] As areas were brought under Khmer Rouge control during civil war (1970–1975), but especially after military victory in April 1975, the CPK imposed a radical program of land displacement and dispossession, as hundreds of thousands of men, women, and children were evacuated from Cambodia's cities and market-towns and reassembled in hundreds of agricultural collectives and work-sites throughout the country.[12] As explained in its Four-Year Plan, developed between 21 July and 2 August 1976, the CPK identified two basic economic objectives. The first was "to serve the people's livelihood, and to raise the people's standard of living quickly, both in terms of supplies and in terms of other material goods."[13] This was to be accomplished through the pursuit of a second objective, to "seek, gather, save, and increase capital from agriculture."[14] To this end, the CPK adopted an overall economic strategy that conformed to the broad development objectives of members of the Non-Aligned Movement, namely the promotion of industry through a program of import-substitution industrialization (ISI).[15] Briefly stated, advocates of ISI promoted an economic approach based on self-sufficiency, whereby less-developed countries would initially domestically produce previously imported, simple consumer goods and then domestically produce a wider range of more sophisticated manufactured items. A CPK document from 8 May 1976 for example specifies that "We will decrease importing items next year, including cotton and jute, because we are working hard to produce ours. We will import only some important items such as chemical fertilizer, plastic, acid, iron factory, and other raw materials."[16] According to this document, such a strategy was deemed most appropriate, for it was concluded that "by taking loans from the West or Eastern Europe" the CPK would lose its "self-reliant stance."[17] To this end, the CPK concentrated on items that could be effectively produced domestically, including plates, pots, spoons, mosquito-nets, shovels, hoes, and so on. In practice, most of these light industries never materialized, although textile factories and some machine shops were in operation.

With respect to the ability to increase capital through foreign trade, CPK officials turned to the country's historic comparative advantage: agriculture. As illustrated in numerous documents, high-ranking members of the CPK readily understood that Democratic Kampuchea was replete with "such things as land, livestock, natural resources, water sources such as lakes, rivers and ponds" and that these "natural characteristics have given [the country] great advantages compared with China, Vietnam, or Africa."[18] More precisely, the Khmer Rouge leadership recognized that rice was key to raising capital.

It is necessary at this point to consider more closely the administrative geography of Democratic Kampuchea (see Figure 1). Democratic Kampuchea was partitioned into several zones (p*humipeak*); in turn, zones were divided into regions or sectors (*damban*), districts (*srok*), communes (*khum*), and cooperatives (*sahakor*). At the most basic level, communes were composed of multiple villages (*phum*) while cooperatives consisted of several hundred people (see Figure 2). The CPK's spatial organization of governance was pivotal for administrative practices, including the mobilization of laborers for work-projects, such as clearing forests, excavating canals and reservoirs, and constructing dams and dikes. Each political sub-division (e.g., zone, region, district, or commune) was governed by a three-person committee composed of a secretary, deputy secretary, and member. The Zone Committee, accordingly, was responsible for overseeing the implementation of Party plans and policies throughout its respective

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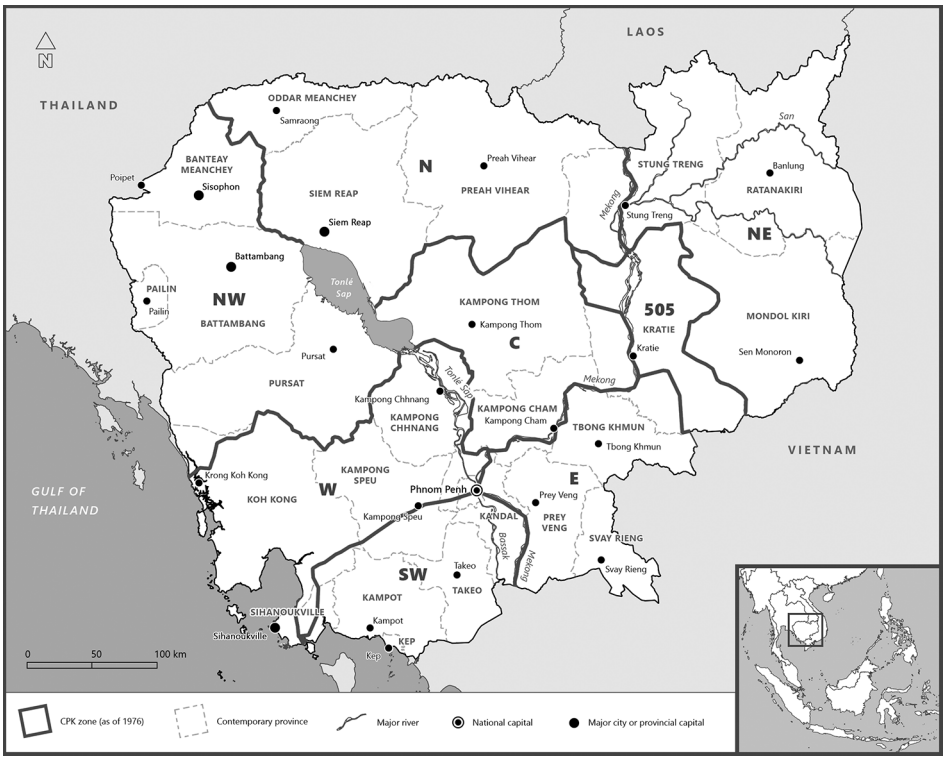

Figure 1. Former provincial boundaries and CPK zone-level administrative boundaries, ca. 1976.

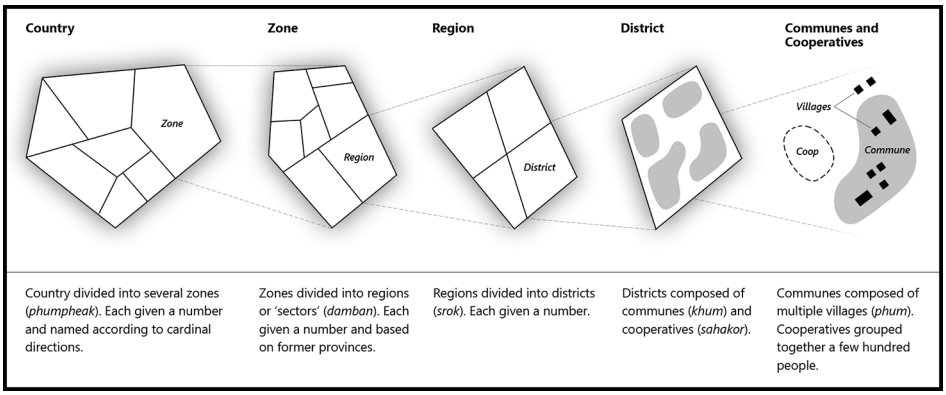
Country
Zone
Region
District
Communes and Cooperatives
Zone
Region
District
Villages
Coop
Commune
Country divided into several zones (*phumpheak*). Each given a number and named according to cardinal directions.
Zones divided into regions or 'sectors' (*damban*). Each given a number and based on former provinces.
Regions divided into districts (*srok*). Each given a number.
Districts composed of communes (*khum*) and cooperatives (*sahakor*).
Communes composed of multiple villages (*phum*). Cooperatives grouped together a few hundred people.

Figure 2. Territorial organization of Democratic Kampuchea.

zone, and for delegating plans and policies to all other levels under its purview. Likewise, the committees at the region, district, or commune level fulfilled similar functions of implementing tasks designated by the CPK upper echelon.

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Efforts to rapidly expand agricultural production, notably rice, was not predicated on some misguided attempt to promote an agrarian utopia or a radical reading of Marx; rather, these efforts were part-and-parcel of a pragmatic course of action based on capitalist principles and a recognition that different zones exhibited different comparative advantages. To this end, Khmer Rouge policies marked less a rupture of previous economic approaches and more a continuation of policies advocated by the former French colonial government and that of Norodom Sihanouk from the 1950s onwards.[19]

As explained in the Party's Four-Year Plan, "For 100,000 tons of milled rice, we would get [US] $20 million; if we had 500,000 tons we'd get $100 million .... We must increase rice production in order to obtain capital. Other products, which are only complimentary[,] will be increased in the future."[20] Consequently, it was necessary for the CPK to expand agricultural lands through the clearance of forests and the construction of elaborate irrigation projects consisting of dams, dikes, canals, and reservoirs. Indeed, for the CPK, the overriding obstacle for increased rice production was the problem of water. As detailed in the Four-Year Plan, it was necessary to "increase the degree of mastery over the water problem from one year to another until it reaches 100 percent by 1980 for first-class rice land and reaches 40–50% for ordinary rice land."[21] The Plan continues: "In order to gain mastery over water there must be a network of dikes and canals as the basis. There must also be canals, reservoirs, and irrigation pumps stationed in accordance with our strategy."[22]

Appropriate water-management policies require measures and procedures that are suitable for specific physical geographic conditions.[23] To what extent did the CPK leadership propose or adopt appropriate policies? Margaret Slocomb writes that CPK policy "failed because the administration of their plans did not respect the adaptations that Cambodian rice farmers had learnt to make to subtle variations in soil quality and topographical and climatic conditions to ensure their livelihood."[24] This is a bold assertion but requires documentary evidence. We know that many policies were hastily conceived and that many were found wanting. However, to simply identify the lack of details is to miss the larger picture, for it is insufficient to highlight one or two poorly conceived or incomplete sections of, say, the Four-Year Plan, while neglecting to see these plans in their totality.[25]

In a statement delivered during the third week of August 1976, the Party Secretary, Pol Pot, emphasizes that "It is the Party's wish to transform agriculture from a backward type to a modern type in ten to fifteen years."[26] Throughout his remarks Pol Pot identifies the varied physical geographies of Democratic Kampuchea. With respect to the Northwest Zone he explains:

> We must grasp the nature of the available soil and the nature of water resources. Having grasped the geography, we can assign first-grade land to two harvests and second-grade land to one. In addition, we must estimate the water-power available. We must know where to construct dams and where to dig canals.[27]

Likewise, he explains that in the Southwest Zone "soil in Region 25, if harvested twice, will yield sizable crops, compared with Region [33] which produces only 1.5 tons per hectare; Region 25 produces four to five tons per hectare, a very significant difference."[28] In recognition of the country's spatial variability Pol Pot called for the production of "charts, lists and figures for certain zones and regions so that [cadre] can observe whether these are in accordance with reality or not."[29]

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There is no documentary evidence—of which we are aware—of an objective, empirical assessment conducted by the CPK on local hydrology, soil types, rainfall patterns, and other critical variables that might affect agricultural productivity. That being said, interviews with former Khmer Rouge cadre and other survivors indicate that (1) local knowledge was used in the planning and implementation of various irrigation schemes and (2) Chinese engineering and technical assistance were widely employed. It is not far-fetched to speculate that relevant planning documents and environmental assessments remain classified in Chinese archives.[30] Regardless, documentary evidence does suggest that CPK officials were certainly *aware* of local conditions and of the salience of geomorphology and hydrology in the construction of irrigation schemes. To this end, a systematic mapping of actual irrigation schemes is required to better understand the actual construction of dams, dikes, reservoirs, and canals.

Mapping Khmer Rouge Irrigation Schemes

In his discussion of Khmer Rouge irrigation projects, Himel explains

> the hydrology of the overall system was deeply flawed. Canals of ten kilometers in length were dug connecting adjacent watersheds together" and that "natural drainage patterns were badly disrupted and the new routes caused unexpected flows to occur that could not be predicted by the local people who had lived there for their entire lives.[31]

Following Tyner and Will, we agree with Himel that many water management strategies initiated by the Khmer Rouge were improperly designed; and that those projects that failed led to a number of disastrous consequences.[32] Where we differ is the blanket assessment that the overall approach was deeply flawed. Lacking any scientific study of Khmer Rouge irrigation, scholars are confronted with the impossibility of making any claims as to the scale and scope of water-management under the CPK, let alone its effectiveness.[33] Accordingly, we conducted a two-year mixed-methods study in an effort to map the complex system of dams, dikes, canals, and reservoirs built during the Khmer Rouge regime.

Using digital satellite imagery, aerial photographs, archival records, and field observation, the extent of Khmer Rouge irrigation schemes was systematically documented and analyzed. This project extensively used Landsat 1 through 4 Multispectral Scanner (MSS) sensor data, which is available beginning in 1972. There is therefore satellite data that pre-dates Khmer Rouge irrigation construction, is contemporaneous with construction, and post-dates construction. This satellite data has a moderate spatial resolution of 79 meters and has proven efficient at detecting moderate size features, such as reservoirs, dikes, and canals. Importantly, even with a 79m pixel resolution, most canals and dikes that are 5m or wider can be detected, so long as they are more than a few hundred meters long. This is because the spectral signal of water especially, so dominates the larger pixel that the irrigation features can be easily seen. We supplemented Landsat data with declassified satellite imagery obtained via the KH-9 Program (codenamed HEXAGON), a series of photographic reconnaissance satellites launched by the United States between March 1973 and 1980. HEXAGON data provides ground resolution at greater than seven meters, thus providing finer detail than using only Landsat images.[34]

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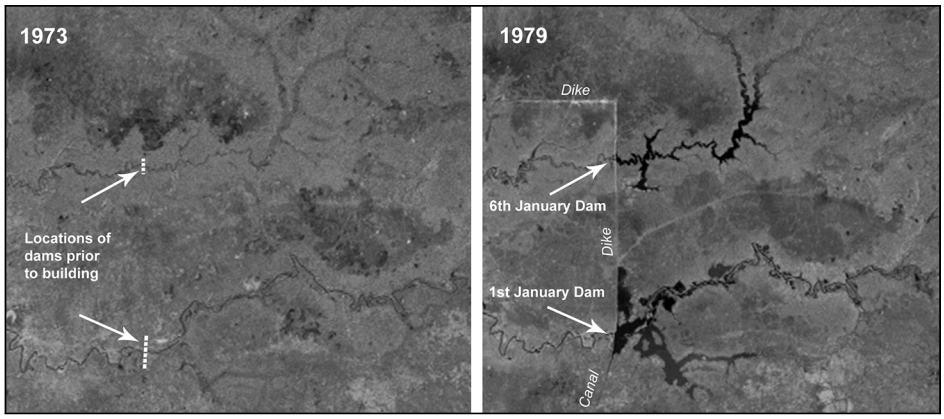

Figure 3. MSS images (band 4 only) from 1973 and 1979 showing the differences between the two time slices. The 1973 image has the locations of the yet to be built dams shown as dotted lines. The 1979 image shows the two large reservoirs that resulted from damming of the rivers.

Pre-CPK (1973–1975) and post-CPK (1979–1984) images were analyzed for the entirety of Cambodia. All images were geo-registered, atmospherically corrected, and assembled into a photomosaic. For this analysis we used two techniques to help differentiate water from land: a Normalized Difference Water Index (NDVI) analysis, and a Corrected Transformed Vegetative Index (CTVI) analysis. Both procedures approximate overall green leaf area, vegetative condition, and volume of biomass. Briefly, these geospatial technologies enable us to successfully identify water and the presence of vegetation, as well as the nature of vegetation health and biomass. In turn, we are able to identify the presence of human-produced features, such as dams, dikes, canals, and reservoirs for imagery prior to and following the Khmer Rouge regime (see Figure 3). During the summers of 2015 and 2016, site visits were conducted to field-check satellite-based observations of irrigation schemes. In addition, local elders, survivors, and former Khmer Rouge cadres were consulted on the construction and utilization of irrigation schemes.[35]

The Scale and Form of Khmer Rouge Irrigation Schemes

It is a well-entrenched myth that the Khmer Rouge recklessly imposed a chess-board pattern of agricultural fields across the entirety of the country; and that rice production was to be tripled regardless of local conditions. In part, this myth derives from Pol Pot, for it was the Party Secretary who demanded that the country triple annual rice production to a national average of three tons per hectare.[36] Likewise, both survivor testimony and archived documents attest to the efficiency and hence desirability of rice plots to be systematized in spatial arrangement and of uniform size. It is a mistake, however, for scholars to subsequently take as fact the idea that the CPK thoughtlessly applied uniformity to agriculture and irrigation throughout the country. Indeed, Pol Pot himself recognized earlier miscalculations, noting that it was incorrect to set a target of three tons per hectare. With hindsight, Pol Pot explains that the CPK "rearranged and improved [its] line, classifying some places as ones which could be

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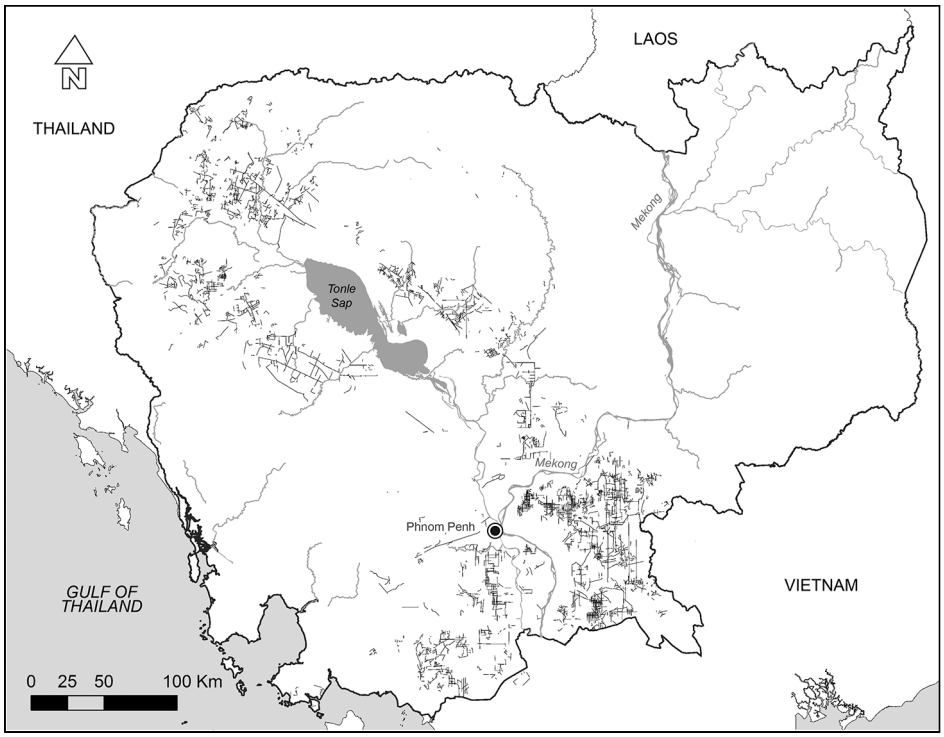

Figure 4. Canals and dikes constructed during the Cambodian genocide.

harvested once a year and other places as ones which could be harvested twice a year."[37]

We raise this observation not to exculpate Pol Pot or other Khmer Rouge leaders; rather, we call attention to the disconnect between official rhetoric, material reality, and the necessity of empirically grounded scholarship. Indeed, we maintain that such an approach is needed to better document and hence hold accountable those responsible. If, for example, documentary evidence indicates that Khmer Rouge officials were aware of local conditions, but failed in the implementation of projects, this suggests a particular organization of decision-making quite apart from a simple top-down understanding.

To this end, we question the rote descriptions of Khmer Rouge irrigation development that typifies much scholarship. Pijpers for example writes that men and women "were put to work digging canals, constructing dikes and dams, laying out rice fields in rectangular 1 ha plots and trying to grow high-yielding rice varieties under unfavorable conditions."[38] He continues that CPK's overall policy was to provide "at least two crops a year and preferably more; production of other crops was severely curtailed and tobacco and maize fields were turned over to rice."[39] With respect to irrigation systems, Pijpers roundly criticizes the CPK's promotion of "a *nationwide* chessboard of levelled 1 ha plots in productive areas and in the reclaimed forest" and the "creation of reservoirs by constructing long dykes along depressions or by damming natural depressions and valleys."[40] To what extent does Pijpers conclusions hold?

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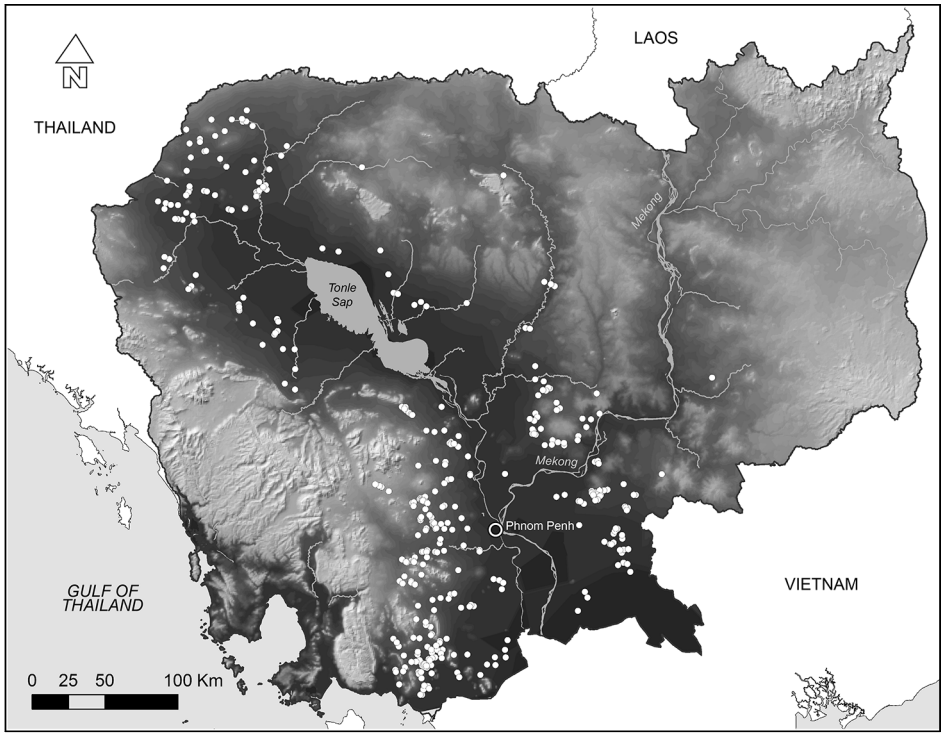

Figure 5. Reservoirs constructed during the Cambodian genocide.

Throughout the Khmer Rouge regime approximately 7,000 kilometers of large-scale canals were constructed (see Figure 4).[41] It is important to note that our methods only detect the larger canals and dikes, typically greater than 5m in width. Typically, these larger canals have smaller canals/ditches evenly spaced at 100m intervals. Accordingly, our methods are unable to capture the (potentially) tens of thousands of kilometers of smaller-scale features, including innumerable tributaries and dikes. Likewise, over 350 reservoirs were built during this period (see Figure 5). Spatially, the majority of canals and reservoirs are located throughout the plains surrounding the Tonlé Sap. Here indeed are found extensive rice fields arranged in one-by-one-kilometer grids. However, one should acknowledge that on a floodplain, a grid-patterned system of dikes and canals is enormously efficient. Indeed, this is why the French used similar geometric arrangements throughout their rice plantations both in Cambodia and Vietnam.[42]

A notable concentration is found in the Northwest Zone; this corresponds more precisely with Region 5 (centered around Sisophon). As detailed by Ben Kiernan, Region 5—but the Northwest Zone in general—was in many respects ground-zero for the Khmer Rouge's attempt to rapidly increase agriculture. This area received considerable influx of forced laborers, transferred mostly from the Southwest and West Zones. Moreover, massive irrigation projects were initiated in Region 5, with labor conscripted from throughout the Northwest Zone. According to Kiernan, attempts to establish region-wide schemes ultimately failed, causing the Khmer Rouge leadership

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to reform its labor-force into smaller units.[43] This accounts, in part, for the complexity and variety of smaller-scaled irrigation schemes (see below). A secondary concentration of irrigation projects is located in present-day Battambang and Pursat Provinces. These areas also fell under the purview of the Northwest Zone and received countless men and women transferred from other regions to satisfy incessant labor demands. Battambang in particular was part of Cambodia's main rice-growing regions and this continued under the Khmer Rouge.

Additional concentrations are located in the East and Southwest Zones. The East and Southwest Zones were the two most important areas of pre-war CPK organization.[44] As such, it is within these locations that we identify some of the earliest irrigation projects initiated, with some dams or canals begun in 1973 or 1974. Typified especially by rolling hills and low-lying mountains, the Southwest Zone consists of many small-scale reservoirs and canals; this contrasts with the overall larger schemes found through the central plain. In fact, the stereotypical chessboard arrangements are conspicuously absent in these areas, as are the massive geometric schemes found surrounding the Tonlé Sap.

The absence of large-scale irrigation schemes in the extreme southwest and northeast sectors of the country is noteworthy. As mountainous regions, these areas have historically been dominated not by rain-fed lowland rice but rather upland or "mountain" rice. Typically, the cultivation of upland rice is performed as a type of shifting cultivation. During the dry season, vegetation is cleared for planting and underlying brush is burned. This provides clearance for planting and natural fertilizers. Seeding generally occurs between April and June with harvesting taking place in August. Throughout the entirety of the Khmer Rouge regime, less attention was apparently directed toward these areas in the pursuit of increased rice yields; notably, there was no concerted attempt to apply lowland techniques or "chessboard" irrigation systems to these locations.

In the broadest sense, irrigation schemes are constructed for one of two purposes: to contain and deliver water locally, or to deliver water over longer distances. Based on our mapping we forward a six-class typology of irrigation schemes; collectively, these represent the most common spatial forms of water-management systems built by the Khmer Rouge (see Figure 6). Our typology is based primarily on the nature of storage and delivery of water, as well as the relationship of the structure to existing hydrology and geomorphology.[45] More precisely, we identify six distinct categories: external storage, internal storage, linked storage, segregated storage, large-scale canal systems, and topographically controlled systems.

External Storage

External reservoirs are bound by dams, dikes, and canals; these are designed to store water upstream of the area being irrigated. External reservoirs are typically large and no rice production occurs within the flooded areas of the reservoir. To date, we have identified three irrigation schemes classified as having external storage. Exemplary is the Stung Chinit irrigation scheme, previously illustrated in Figure 3. The Stung Chinit scheme is actually a complex system composed of 2 large external reservoirs, the January 1st and January 6th reservoirs.[46] The northernmost January 6th reservoir is geometric and bound by a north-south trending canal/dike system to the west, and two east-west trending dikes to the north and south of the reservoir; these are exactly two kilometers apart. The surface area of the reservoir is 18 km^2 and is drained by

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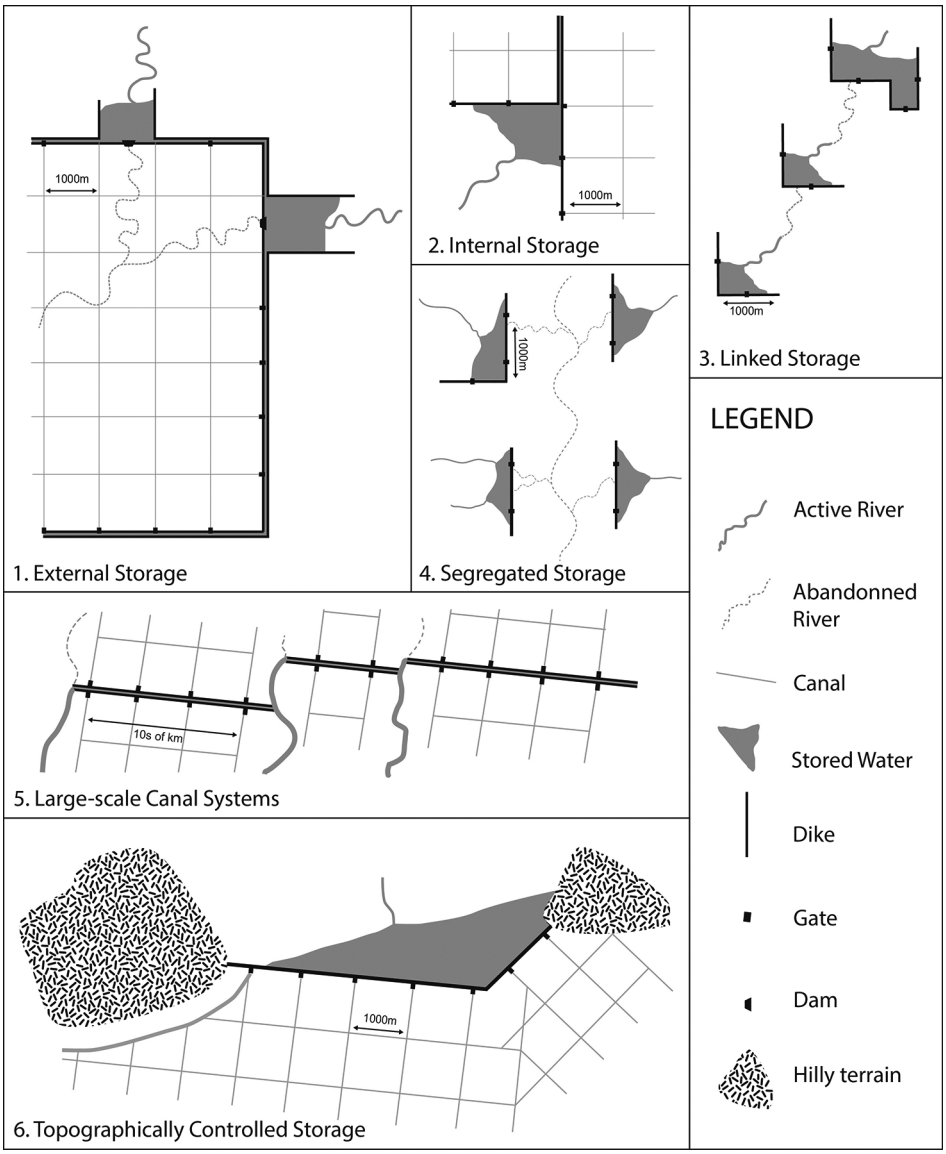

Figure 6. Typology of Khmer Rouge irrigation schemes.

the north-south trending canal and large flow control gate to the west. The southern January 1st reservoir (16 km^2) is organized slightly differently. While still bound by the linear canal/dike to the west, the northern and southern bounding dikes tend to parallel the main flow lines of the river that feeds the reservoir. The January 1st reservoir, also, is drained by the same north-south trending canal as the January 6th system. The canal that connects these two reservoirs is over 70km long and delivers water as far away as 40km. This main canal originates near the national highway,

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approximately 15km southeast of Kampong Thom, and extends eastward from the highway for 16km, then turns southward for exactly 16km (with a slight bend westward) before it takes several other 90 degree turns over the course of 43km. The canal is bound by two earthen dikes; several smaller canals, each spaced exactly 1km apart, feed from the larger canal into the area being irrigated via small control gates. In many respects, the Stung Chinit irrigation system exemplifies the stereotypical image of Khmer Rouge irrigation schemes; in reality, it is rather unique.

Internal Storage

Internal reservoirs were common throughout Democratic Kampuchea and ranged from very small (1km^2 surface area), to very large (e.g., Trapeang Thma covering over 40km^2 when flooded). Internal storage systems are designed to fill upstream, allowing rice production in the flooded areas while still enabling water to be released via a series of floodgates for irrigation downstream. The reservoirs are bounded by earthen dikes and have one or more large canals to deliver water to areas tens of kilometers away. Often, these reservoirs are square or rectangular, with the bounding dikes taking multiple right angle turns. Dikes are often, but not always, aligned along a north-south or east-west axis.

Linked Storage

When multiple dams are built along a single river or stream, we identify these as linked storage irrigation schemes. The resultant reservoirs are ultimately connected to each other via the original stream and, occasionally but rarely, by canals. Dikes are commonly built at right angles to each other, and most reservoirs are bound by two to four straight-walled dikes at 90 degrees to each other. Linked reservoirs are typically small, with each reservoir covering no more than 3km^2 at maximum capacity. Preliminary observation suggests that most linked storage systems are concentrated both in the southeast and north of the Tonlé Sap in present-day Kampong Thom Province. Moreover, it appears as if each local reservoir was built independently by a local district or commune and that there was little to no awareness of adjacent reservoirs as each was being built. In other words, anecdotal evidence suggests that different and uncoordinated decisions were made to establish dams and reservoirs along the same stream, resulting in a linked system that, in operation, would be prone to problems. For example, the higher upstream a reservoir is, the more it may impact the hydrology downstream (e.g., reducing water availability or, with uncontrolled release, potentially flooding areas downstream). The existence of linked storage systems may provide insight into the decision-making process (or lack thereof) with respect to the initiation of irrigation projects. Zone secretaries may have encouraged region or district secretaries to initiate local projects and yet failed to articulate these as a coherent whole. The resultant projects would thus potentially and negatively impact one another. This in and of itself could contribute to the observation that many dams failed catastrophically. Ironically, each individual scheme may have taken seriously local conditions; the failure was thus not at the local level but derived from a lack of awareness and coordination on a regional scale.

Segregated Storage

Segregated storage refers to the damming of multiple tributaries of a single river. Each storage reservoir functions separately and appears to have no impact on nearby reservoirs, except if they have been connected by a canal. One reservoir will typically not

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lead to the flooding or drying of another reservoir. These are commonly found in flat-bottomed valley settings, such as those north of the Tonlé Sap in Kampong Thom Province. Similar to linked storage systems, preliminary but anecdotal evidence suggests that each individual reservoir may be been built independent of other proximate reservoirs; there may or may not have been regional coordination.

Large-Scale Canal Systems

The construction of isolated canals throughout the flatlands of Democratic Kampuchea was common and in many places these did (as observed by both Pijpers and Himel) cross watershed and sub-watershed boundaries. Such canals are typically simple and relatively small structures bound by two earthen dikes. However, there also exists large-scale canal systems that were designed to carry water for tens of kilometers before adjoining another river, or alternatively to provide irrigation across a wide area. The longest canal built by the Khmer Rouge was the April 17th canal, measuring 97km in length. From its terminus at the village of Rukhak Kiri, it runs along the azimuth 115 degrees for 50 km until it joins the Pursat River, near the city of Pursat.[47] The canal enters and exits the river several times before continuing directly eastward for another 30km, indicating perhaps a greater sensitivity to (and use of) local hydrologic conditions. Parallel to the April 17th canal are two additional canals (both north and south), each roughly 12km away from the main canal. The southernmost canal, measuring approximately 41km, is now entirely abandoned. The northern canal, conversely, runs for 35km and remains in use. This latter canal, unlike the April 17th canal, crosses small streams with complete disregard of local hydrology and geomorphology. This may indicate a different level and understanding of hydro-engineering as it was constructed.

Topographically Controlled Systems

These irrigation schemes most commonly consist of dams (and resultant reservoirs) being constructed where major topographic features on the landscape have been used as natural barriers to water flows. The Kamping Puoy irrigation system in present-day Battambang Province, for example, consists of an extensive 6.3km long dam built between two hills. Topographically controlled systems range in size, depending on local geomorphology, but tend toward the massive.

Conclusions

Few studies have empirically documented the scale and scope of Khmer Rouge irrigation schemes. Consequently, grandiose conclusions are forwarded, notably that Khmer Rouge officials ignored or neglected hydrological or geomorphological conditions; that a uniform system of canals, dikes, dams, and reservoirs was imposed uncritically upon the landscape; and the unplanned and uncoordinated construction of these irrigation schemes resulted in widespread failure. These arguments, prone to overgeneralization, are based on minimal or non-systematic field work and reflect more so an inherited narrative regarding Khmer Rouge practices. Indeed, Charles Twining concedes that many scholars simply presume that "irrigation works were often poorly conceived and built, at times contributing to erosion and disturbing natural drainage more than increasing productivity."[48]

In this paper we provide a systematic mapping of Khmer Rouge irrigation schemes with the objective of proving greater clarification of both policy and practice. To begin:

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We calculate *at a minimum* over 7,000 kilometers of large-scale canals and approximately 350 reservoirs were constructed. Archival and field observation materials indicate that CPK officials were aware of and exhibited a sensitivity to hydrologic and geomorphic conditions; but in practice, these concerns were not always heeded. Likewise, evidence suggests a degree of local autonomy in the planning and implementation of irrigation schemes. Based on geospatial technologies, coupled with field observations, we develop a sixfold typology of Khmer Rouge irrigation schemes. Rather than a singular approach to hydro-engineering, we provide evidence that local conditions did figure prominently in the construction of dams, dikes, canals, and reservoirs. This challenges the perception that CPK irrigation projects were ill-planned and (always) prone to failure.

Our work is ongoing. It is premature to conclude that all former Khmer Rouge irrigation schemes failed catastrophically; nor can we satisfactorily assess whether the *majority* failed. We do know that since 1979, but most especially throughout the 1990s and early twenty-first century, many (most?) of the irrigation schemes have been rehabilitated. Other schemes, especially the smaller reservoirs and canals, have been abandoned or re-configured. Moreover, where small linked reservoirs exist and are maintained by local communes, there continues to be minimal coordination or communication between the disparate communities. Consequently, the deleterious effects of upstream dams and reservoirs continue to pose a risk for those located downstream.

Presently, our ongoing work attempts to provide a more robust account of surviving, abandoned, or rehabilitated Khmer Rouge irrigation projects. Likewise, continuing research focuses on calculating the amount of forest cleared by the Khmer Rouge and, by extension, the amount of reforestation/deforestation that has occurred in Cambodia since 1979. Collectively, we maintain that our geographic reconstruction of Cambodia's physical geography will provide insight both into the material context and environmental legacy of the genocide.

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Notes

1. Michael Vickery, "How Many Died in Pol Pot's Kampuchea?" *Bulletin of Concerned Asian Scholars* 20 (1988): 377–85; Ben Kiernan, "The Genocide in Cambodia, 1975–1979," *Bulletin of Concerned Asian Scholars* 22 (1990): 35–40; Patrick Heuveline, "'Between One and Three Million': Towards the Demographic Reconstruction of a Decade of Cambodian History (1970–1979)," *Population Studies* 52 (1998): 49–65; Damien de Walque, "Selective Mortality during the Khmer Rouge Period in Cambodia," *Population and Development Review* 31 (2005): 351–68; and Damien de Walque, "The Socio-Demographic Legacy of the Khmer Rouge Period in Cambodia," *Population Studies* 60 (2006): 223–31.
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8. Himel, "Khmer Rouge Irrigation," 43. Emphasis added.
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11. James A. Tyner, *The Killing of Cambodia: Geography, Genocide and the Unmaking of Space* (Aldershot, UK: Ashgate, 2008).
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14. Party Center, "Four-Year Plan," 51.
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18. Party Center, "Four-Year Plan," 46.
19. Kent Helmers, "Rice in the Cambodian Economy: Past and Present," in *Rice Production in Cambodia*, ed. Harry J. Nesbitt (Manila: International Rice Research Institute, 1997), 1–14; and David Biggs, *Quagmire: Nation-Building and Nature in the Mekong Delta* (Seattle: U of Washington P, 2010).
20. Party Center, "Four-Year Plan," 51.
21. Party Center, "Four-Year Plan," 89.
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24. Margaret Solcomb, *The People's Republic of Kampuchea, 1979–1989: The Revolution after Pol Pot* (Chiang Mai, Thailand: Silkworm Books, 2003), 185.
25. Tyner and Will, "Nature and Post-Conflict Violence," 368.
26. Party Center of the Communist Party of Kampuchea, "Preliminary Explanation Before Reading the Plan, by the Party Secretary," in *Pol Pot Plans the Future: Confidential Leadership Documents from Democratic Kampuchea, 1976–1977*, ed. D. Chandler, B. Kiernan, and C. Boua (New Haven, CT: Yale UP, 1988), 120–63, 131.
27. Party Center, "Preliminary Explanation," 134.
28. Party Center, "Preliminary Explanation," 137.
29. Party Center, "Preliminary Explanation," 133.
30. See for example transcripts of the following interviews: Bou Mao by Sok Vannak (16 June 2011); Mun Mut by Dany Long (16 June 2011); Lot Suoy by Dany Long (no date); Pann Chhuong by Dany Long (18 june 2011); Mean Sambath by Dany Long (12 December 2010); and Chhit Yoeuk by Dany Long (16 June 2011). Transcripts are archived at the Documentation Center of Cambodia, Phnom Penh. We are grateful to the staff at DCCAM for making these transcripts available.
31. Himel, "Khmer Rouge Irrigation," 45.
32. Tyner and Will, "Nature and Post-Conflict Violence," 370.
33. A survey of irrigation schemes was conducted by Pijpers; however, this study did not make use of geospatial techniques, including remote sensing, and thus lacks the geographic comprehensiveness of our study. See Pijpers, *Kampuchea*.
34. All Landsat data was accessed via the United States Geological Survey at http://earthexplorer.usgs.gov. KH-9 data is also available from the USGS for a minimal processing cost.
35. Ongoing research is reconstructing the decision-making processes surrounding the development of irrigation schemes, with special emphasis on the importance of CPK administrative divisions, for example, whether any given project was initiated at the zone, region, or commune level.
36. Party Center of the Communist Party of Kampuchea, "Excerpted Report on the Leading Views of the Comrade Representing the Party Organization at a Zone Assembly," in *Pol Pot Plans the Future: Confidential Leadership Documents from Democratic Kampuchea, 1976–1977*, ed. D. Chandler, B. Kiernan, and C. Boua (New Haven, CT: Yale UP, 1988), 9–35.
37. Party Center, "Preliminary Explanation," 131.
38. Pijpers, *Kampuchea*, 8–9.
39. Pijpers, *Kampuchea*, 8–9. For an extended critique of Pijper's conclusions, see Tyner, *From Rice Fields to Killing Fields*, 106–09.
40. Pijpers, *Kampuchea*, 10. It is notable that Pijpers, almost in passing, remarks that "the standard guidelines were *not followed everywhere and there are small differences as local authorities adapted the standards to local conditions*" (at 10–11; emphasis added).
41. This total is necessarily an underestimate, as the resolution of available satellite image does not allow for the identification of secondary canals.
42. Biggs, *Quagmire*.
43. Ben Kiernan, *The Pol Pot Regime: Race, Power, and Genocide in Cambodia under the Khmer Rouge, 1975–79*, 3rd edition (New Haven, CT: Yale UP, 2008), 219–30. See also Michael Vickery, *Cambodia, 1975–1982* (Chiang Mai, Thailand: Silkworm Books, 1984), 107–29.
44. Vickery, *Cambodia*, 140.
45. In material form, the vast majority of irrigation schemes consist(ed) of earthen dikes and canals with concrete floodgates.

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46. A third reservoir was apparently planned, but never begun. Both reservoirs and their main canals are still functional today, although the bounding dikes appear to have failed repeatedly and have been rehabilitated at several locations.
47. More precisely, this stretch of the canal falls 200m short of 50km.
48. Charles Twining, "The Economy," in *Cambodia, 1975–1978: Rendezvous with Death*, ed. Karl D. Jackson (Princeton, NJ: Princeton UP, 1989), 109–50, 146.

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